

Analysis of the cardiac data

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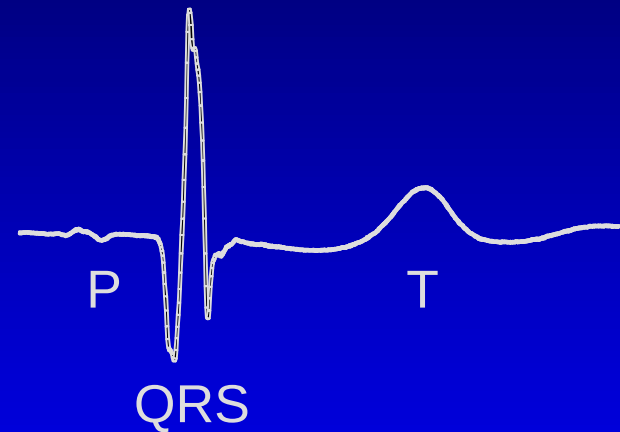


Content

- Introduction to MCG (ECG) signal
- Recording of MCG signal
- Preprocessing of the data
- Analysis based on source localisation
- Analysis of the averaged data
- Dynamical analysis
- Conclusion

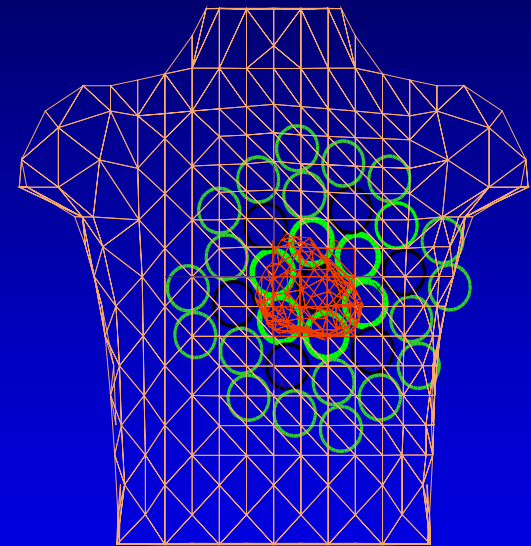
Introduction to MCG (ECG) signal

- Magnetocardiographic (MCG) signal is a result of simultaneous electrical activity of masses of heart cells
- Basic morphologies of the MCG signal are equal with ECG signal
 - Signal consist on 3 basic parts; P wave, QRS complex and T wave



Recording of the MCG signal

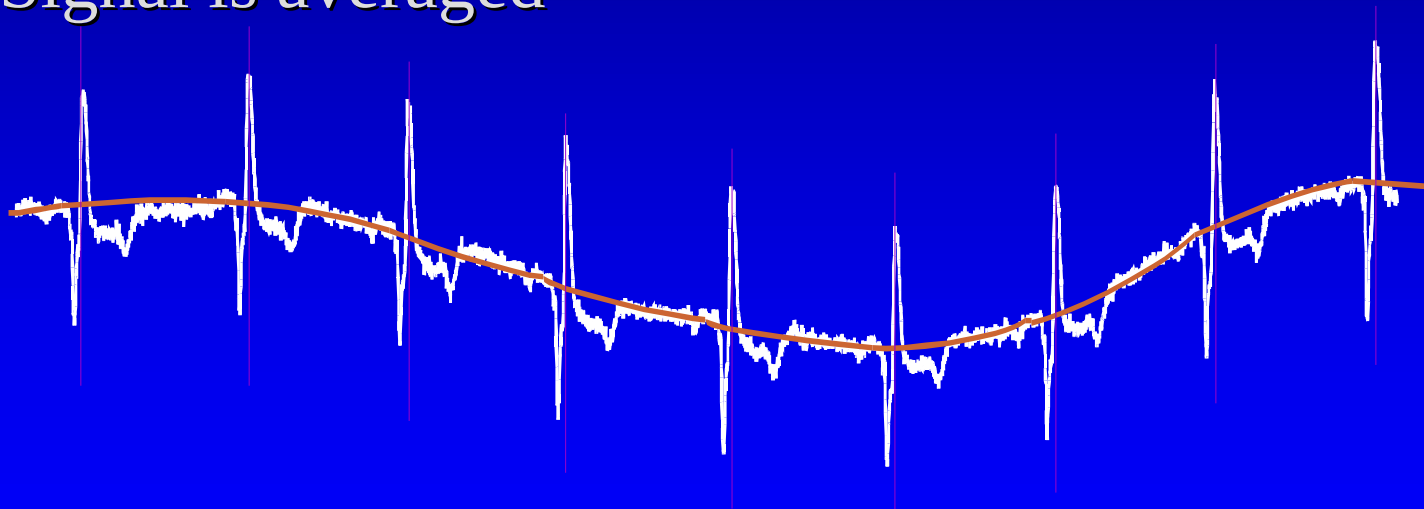
- Signal is recorded, usually in magnetic shielded room, with SQUIDs
- Analog signal is low-pass filtered and digitized
- Most devices nowadays are multichannel devices, enabling mapping studies



Example of measurement grid (Biomag laboratory)

Preprocessing of the data

- Signal is triggered
 - Usually from R peak
- Baseline is detected and subtracted from signal
- Signal is averaged

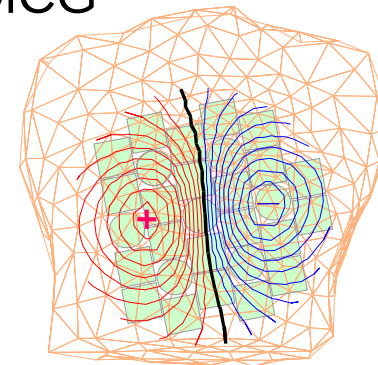


Fitted spline (3-deg) baseline

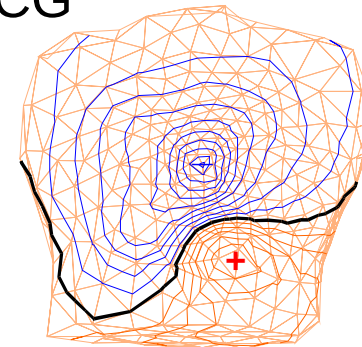
Analysis based on source localisation

- Ill posed problem
 - Some restrictions for the source are needed
- Point source models (current dipoles)
 - For localized sources
- Distributed source models
 - For distributed or propagating sources (activation propagates as wavefronts)

MCG



ECG

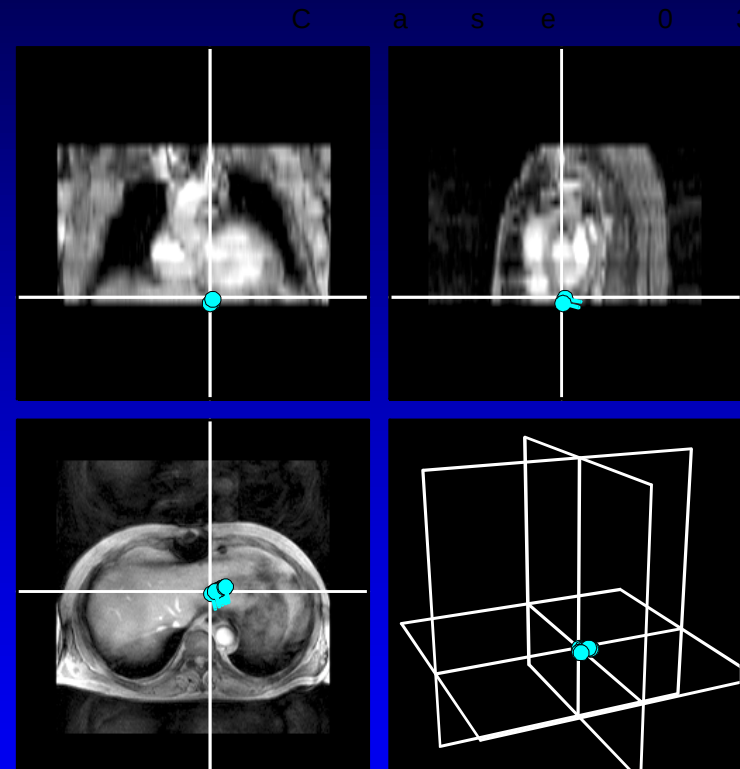


Typical field and potential maps

Analysis based on source localisation (current dipole)

Localization of the arrhythmic foci

- Multichannel MCG data from the beginning of the ectopic beat are used for localization
- Torso is modelled with boundary elements
- Position and direction of the dipole are iteratively evaluated

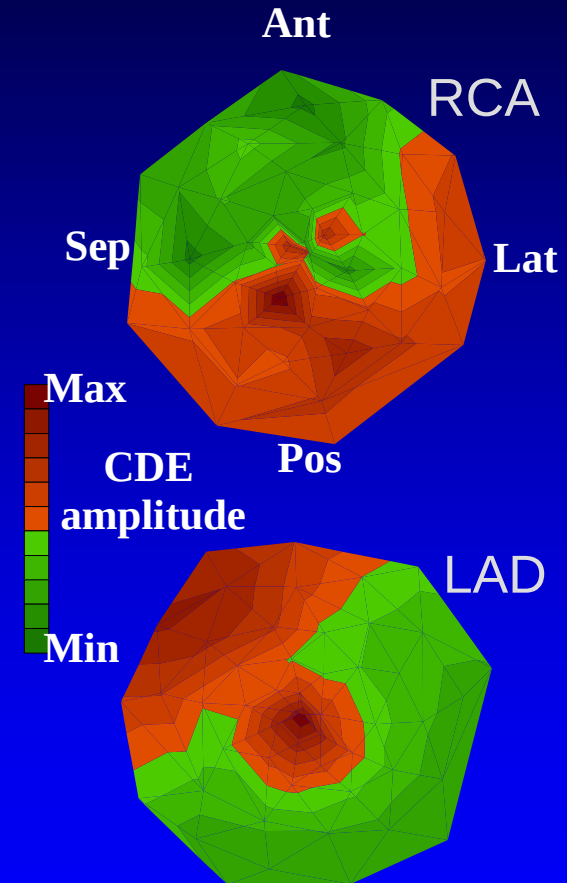


*Localization of arrhythmic foci
(20 points)*

Analysis based on source localisation (current distribution)

Localisation of the injury current

- Data are the difference of the ST-level before and after exercise test
- Current density estimate
 - The magnitudes of the dipoles on preselected surface are evaluated by solving the inverse problem
- The result is visualized (on 3D or bull's eye view)



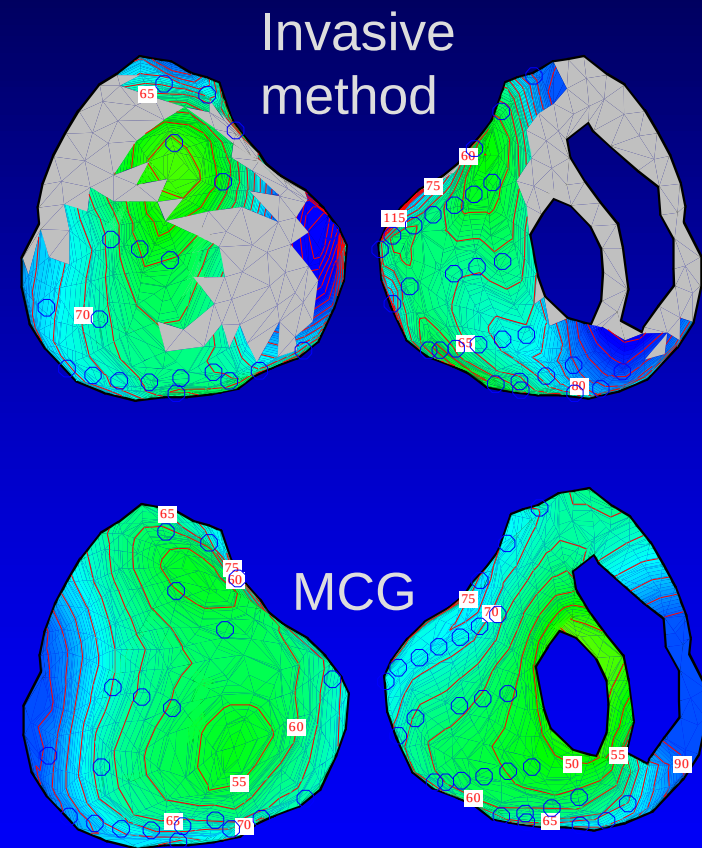
Bull's eye view of the injury current estimate

[K. Pesola 1999]

Analysis based on source localisation (current distribution)

Activation time map

- The positions and the orientations of the dipoles are preset (uniform double layer)
- The sequence of depolarization during the QRS is solved from measured multichannel MCG data



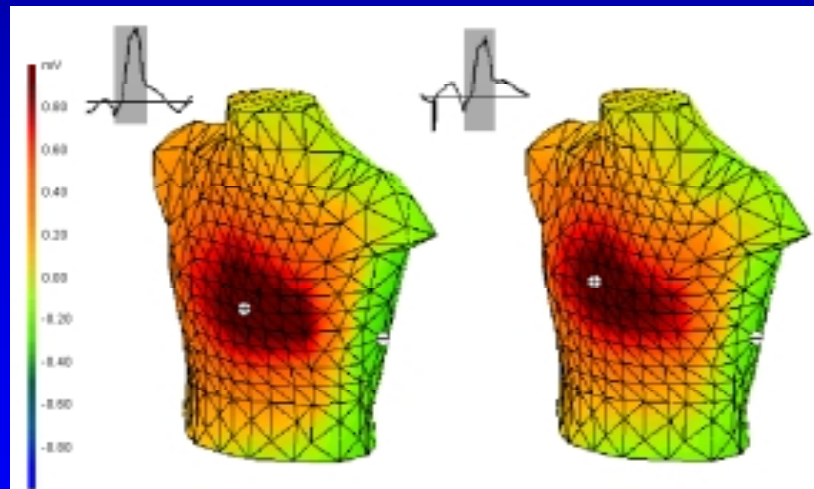
Activation times

[T. Oostendorp 1998]

Analysis based on source localisation

Localization with QRS integral maps

- Mean QRS integral maps during the induced VT and ventricular pacing are evaluated (from BSPM)
[B. Horacek 1979]
- Pacing localization is changed until the maps equal

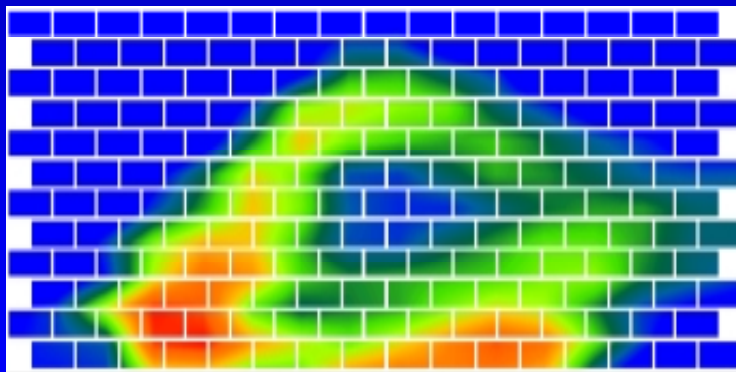


*Mean QRS integral maps over the shaded are
(left: induced VT, right: ventricular pacing)*

Analysis based on source localisation

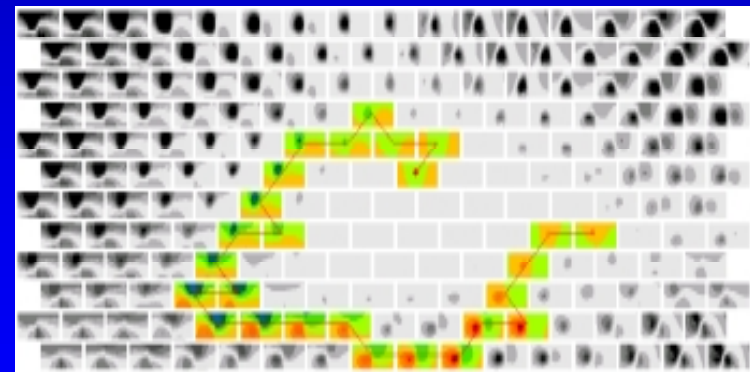
Classification of maps with SOM and LVQ

- SOM was trained with potential (field) maps taken from different patients at different time instants during the QRS
- After training the SOM the distance maps or the trajectories are calculated and classified



Distance maps on SOM

L. Reinhardt 1998

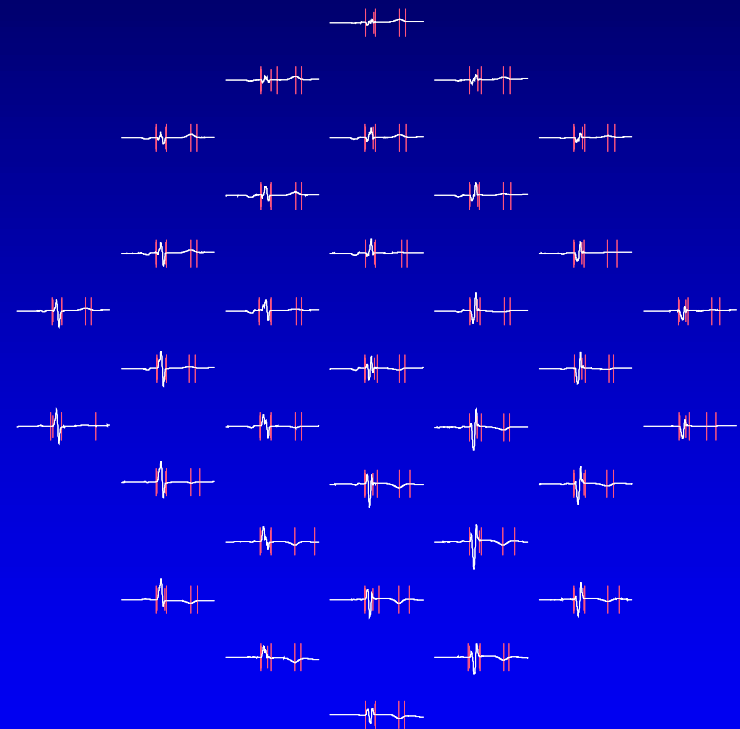


SOM trajectory

L. Reinhardt 1998

Analysis of the signal averaged data

- Basic preprocessing
 - Improves the signal to noise ratio
 - Emphasis cyclic features
- Averaging is usually done somehow selectively

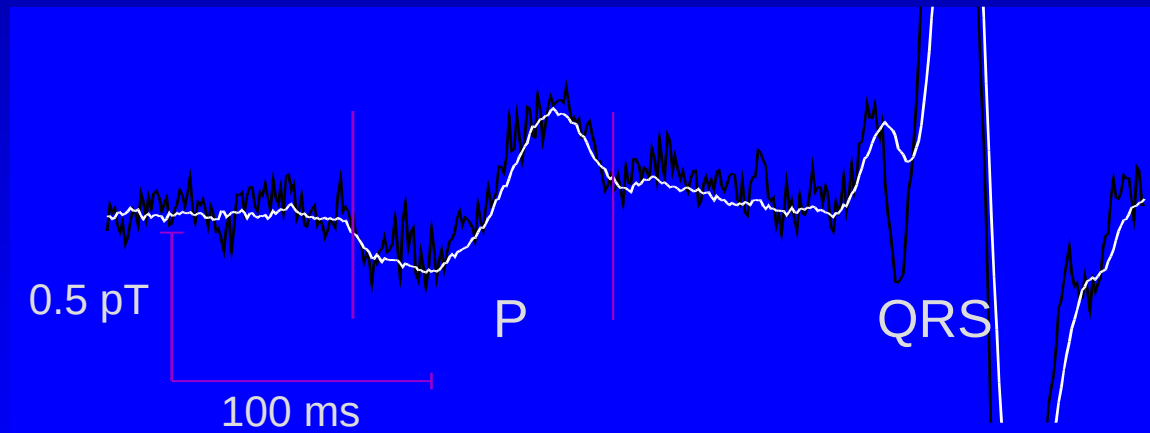


An example of averaged MCG data

Analysis of the signal averaged data

P wave

- P wave is analysed in a similar manner than the QRS (next slides)
- P wave itself is used as trigger instead of the QRS

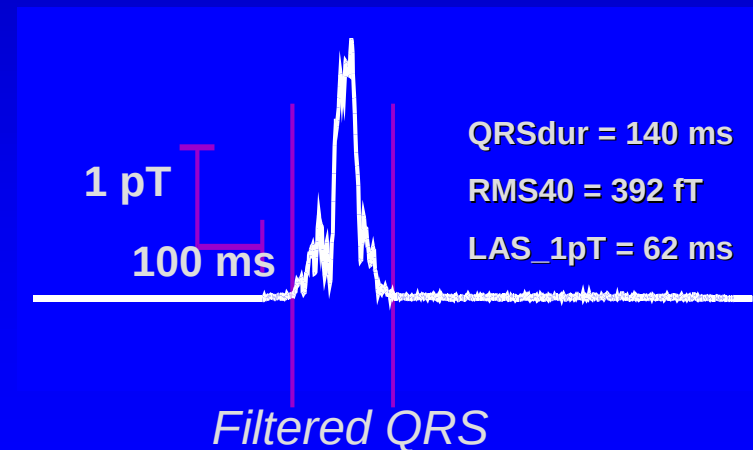
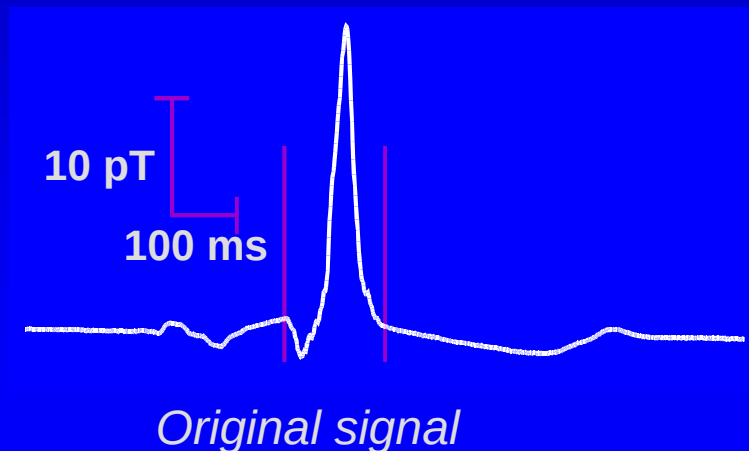


Averaged and non averaged P wave

Analysis of the signal averaged data (QRS complex)

Time-domain analysis

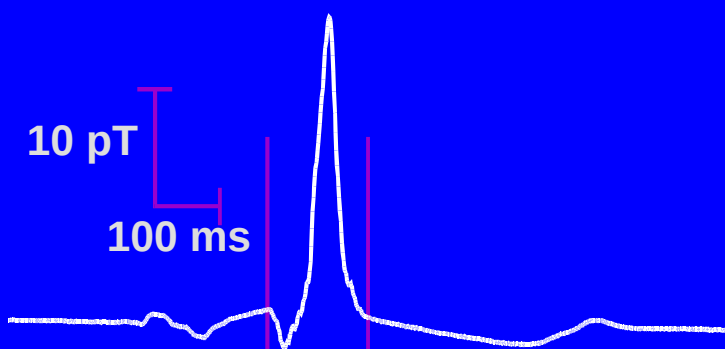
- Late-field analysis (simson method)
 - High-pass filtered (Butterworth 40 Hz) [M. Simson 1983]
 - Envelope of the filtered signal is formed using the Hilbert transform [J. Montonen 1994]
- Parameters: QRS duration, RMS, LAS



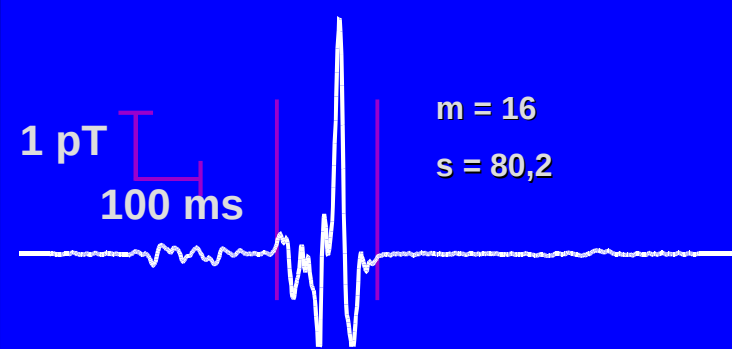
Analysis of the signal averaged data (QRS complex)

Fragmentation analysis

- Fragmentation analysis [P. Endt 1998]
 - Intra-QRS analysis
 - Band-pass filtering 37-90 Hz
 - FIR (binomial)
- Parameters: Number of extrema (M),
Fragmentation score (S)



Original signal

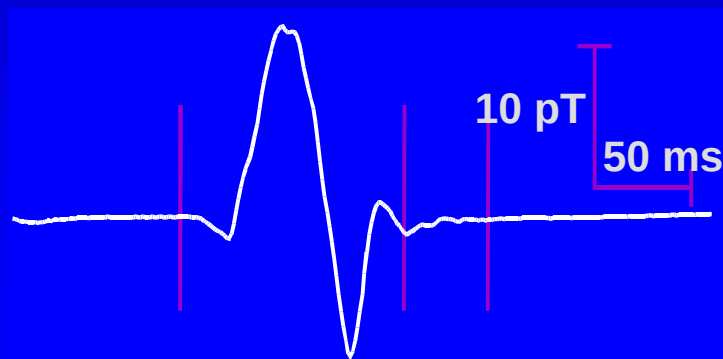


Filtered signal

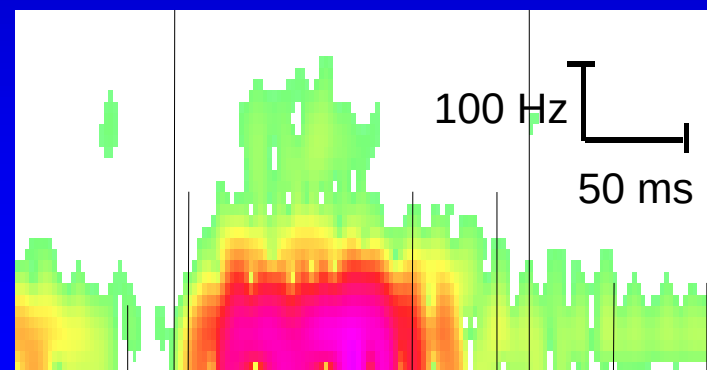
Analysis of the signal averaged data (QRS complex)

Spectral turbulence analysis

- Spectrotemporal analysis [G. Kelen 1992]
 - Intra-QRS analysis
 - Quantities the variability between the short time (24 ms) Fourier spectra within the QRS
- Parameters: QRS duration, ISCM, ISCSD LSCR, SE



Original signal

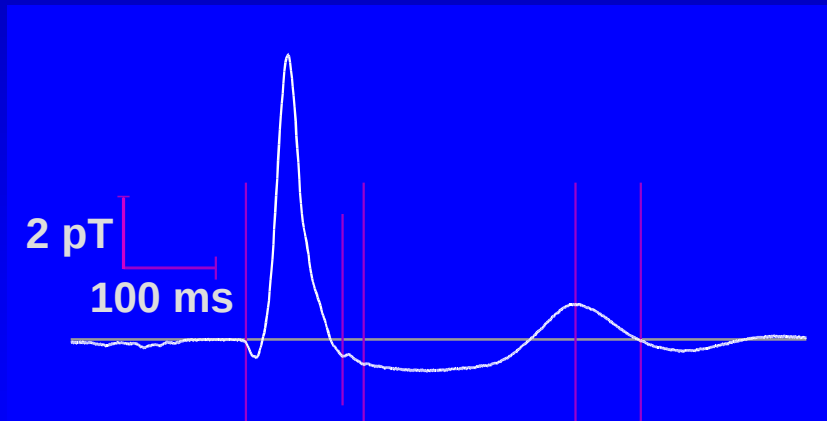


Spectral power of the signal

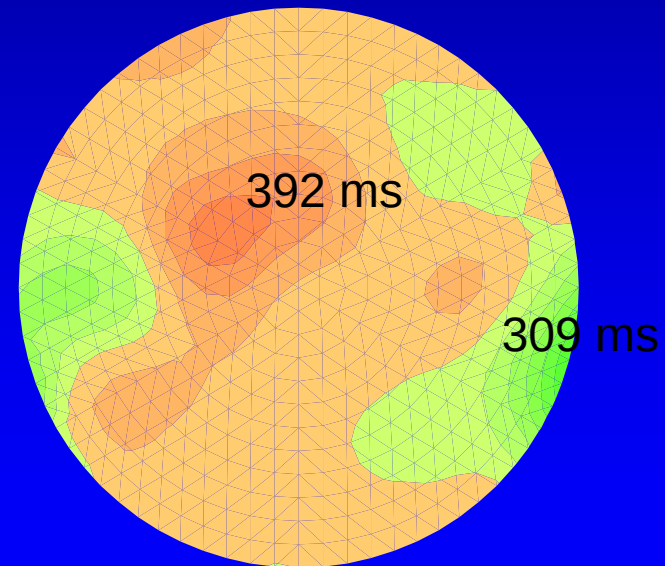
Analysis of the signal averaged data (T wave)

QT dispersion

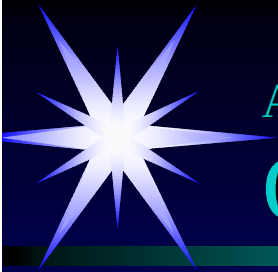
- QT-dispersion analysis
 - Quantities the spatial QT time differences
- Parameters: $\text{Max}(\text{QT}) - \text{Min}(\text{QT})$,
 $\text{Max}(T_{\text{end}} - T_{\text{apex}}) - \text{Min}(T_{\text{end}} - T_{\text{apex}})$, QT_SD, local QTd



QRS and QT durations



QT_{apex} isovalue colour map



Analysis of the signal averaged data (T wave)

Other methods

- QRST-integral
- Relative smoothness (RS) score
- The 90 % duration of the T wave
- Time instants of maximum onset and offset slopes of the T wave
- Symmetry parameter (SR) of the T-wave
- The number of the 'phases' in the T-wave

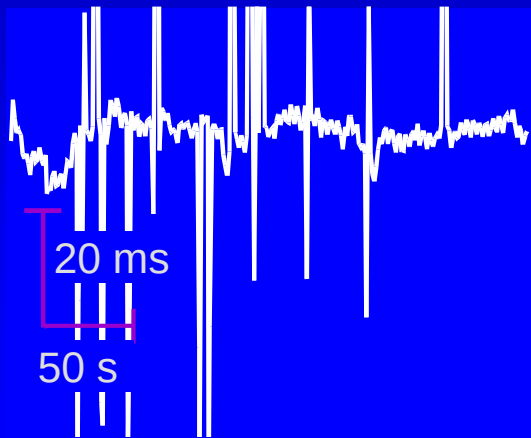


Dynamical analysis

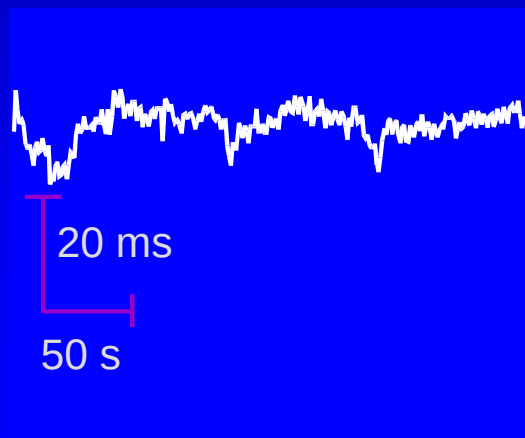
- Analysis of interbeat variation or changes of signal
- ‘Spontanic activity’
 - Prefers long term recordings
 - Heart rate variability, QT dynamics, T-wave alternans, ...
- Interventions, exercise testing
 - Data is recorded before, (during) and after the intervention
 - Especially used for ischemia detection
 - ST-depression, ST- and T-maps, QRS envelope, ...

Heart rate variability

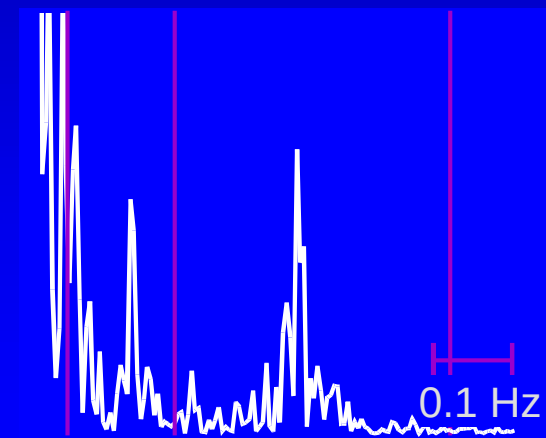
- Time series must be corrected from ectopic beats
- Time domain analysis
 - Average RR time and standard deviation
- Frequency domain analysis
 - Powers of different frequency bands: VLF, LF and HF



Uncorrected RR timeseries



Corrected timeseries

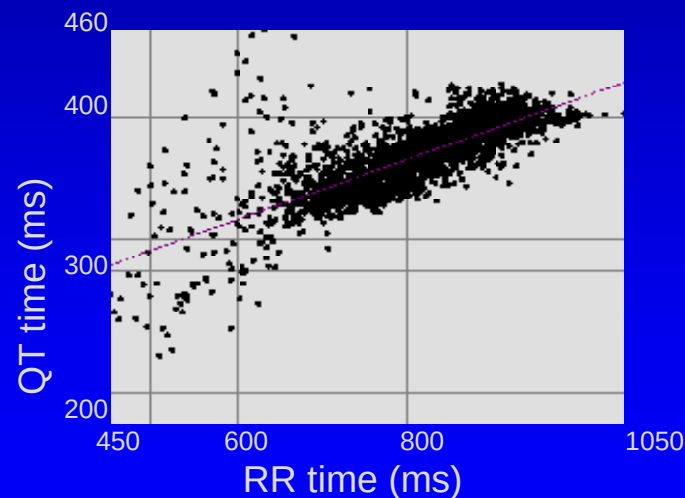


Power spectra

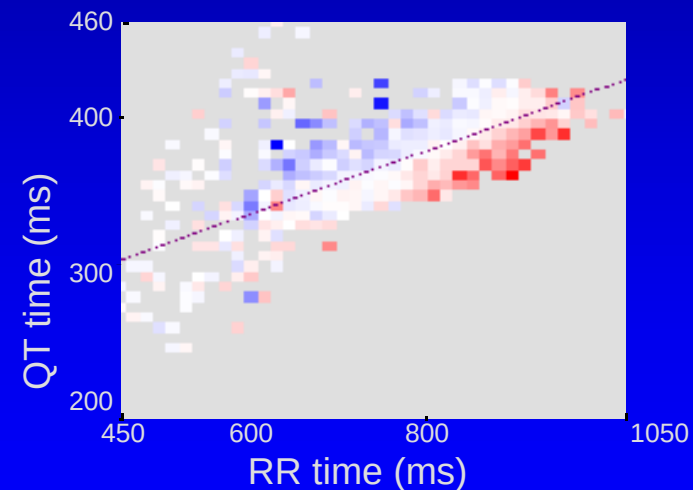
Dynamical analysis

QT dynamic

- QT / RR relation
 - Depends on previous RR intervals
- Time domain analysis of QT timeseries
- Frequency domain analysis of the timeseries



QT / RR plot (24-h Holter ECG)

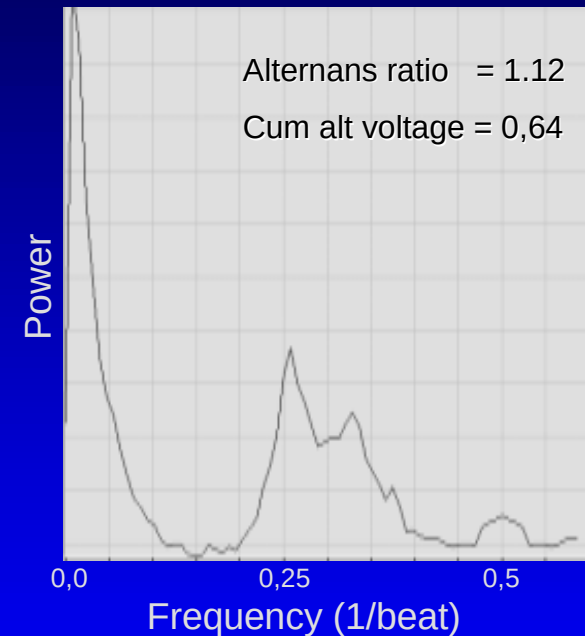


QT / RR plot with colour coded preceding heart rate



T wave alternans

- Consistent 2:1 variation of the waveform morphology
 - Depends on heart rate
- Usually studied in frequency domain
 - [D. Rosebaum 1994]
 - 1. The power spectrum of consecutive T wave amplitudes is formed
 - 2. The frequency 0,5 is scaled with noise value



*Alternans spectrum
(24-h Holter ECG)*

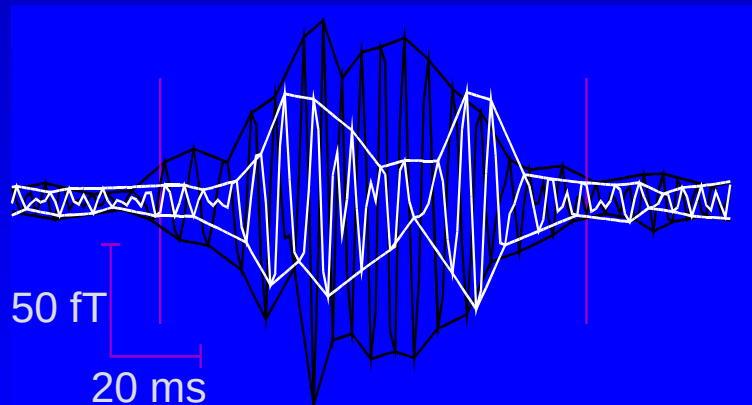
Dynamical analysis (interventions)

Envelope of the QRS

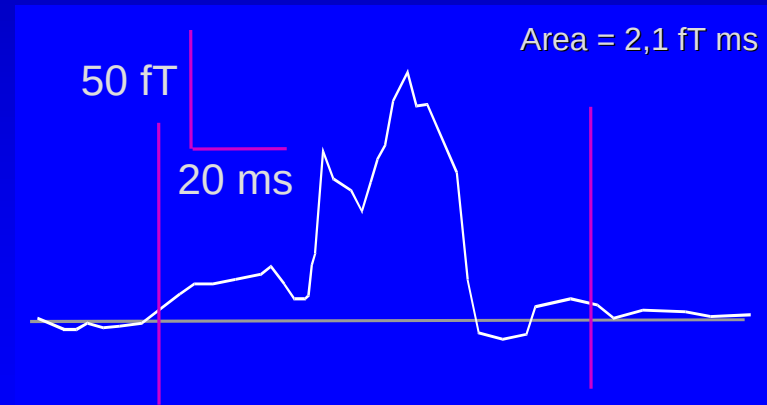
► Detection of high frequency signal attenuation

[S. Abboud 1992]

- The QRS complex is band-pass filtered (150-250 Hz)
- The envelope of the filtered signal is formed
- Difference between the envelopes before and after the interventions are calculated



Filtered signals (before (black) and during exercise (white))

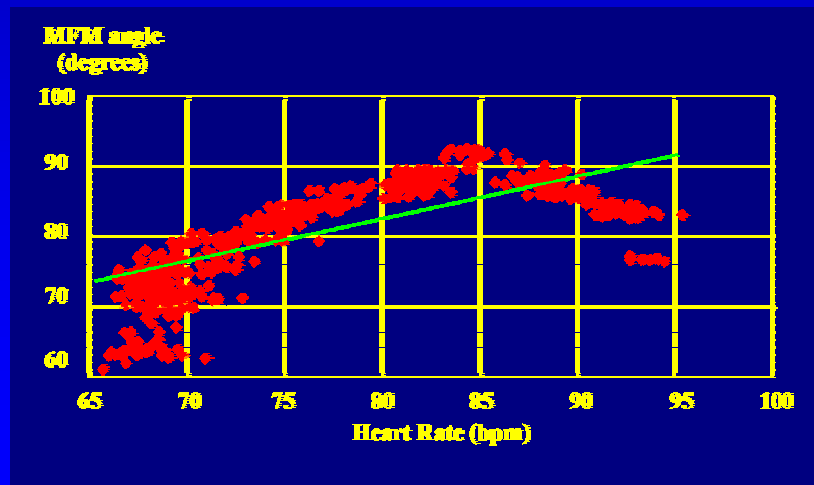


Difference of the envelopes

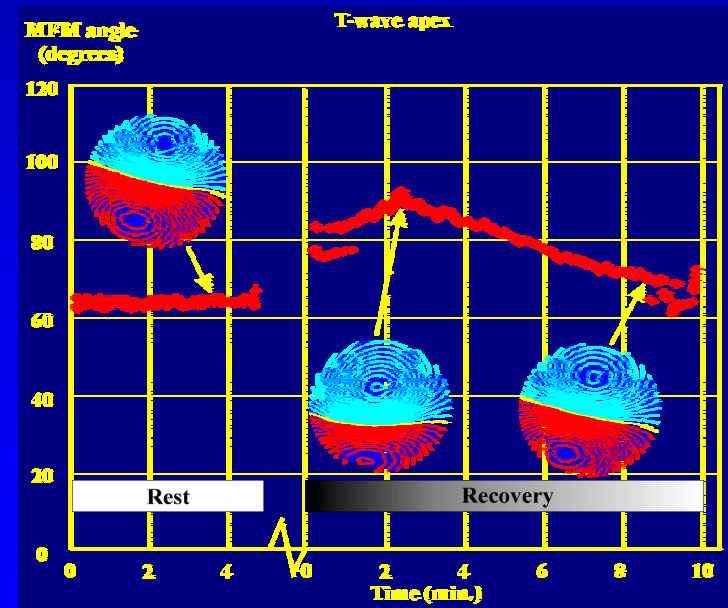
Dynamical analysis (interventions)

Rotation of T and ST integral maps

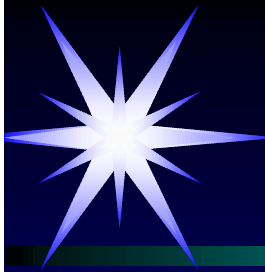
- 1. The integral field maps of either ST -segment or T wave are evaluated
- 2. The angle of the maximum derivative is determined from the integral field maps
- 3. The angle is plotted as the function of time or as the function of heart rate



[P. Takala 2000]



[P. Takala 2000]



Conclusion

- There is no 'ultimate method'
- Different analysis methods for different tasks
- Many ways to analyse one data
- Method to efficiently combine the results of different analyses is needed